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AIR POLLUTION/LAND USE PLANNING PROJECT VOLUME I. SELECTED LAND USE CONTROL POLICIES FOR AIR QUALITY MANAGEMENT

A. S. Kennedy, et al

Argonne National Laboratory

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Three such policies are considered in this study: air pollution impact statements; zoning control in two forms, permitted-use zoning and emission-density-limited zoning; and the prediction of air pollution impacts of comprehensive regional land use plans. This report also considers the source-clustering problem in the Chicago area, specifically in relation to the effectiveness of the three investigated control strategies.

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ABSTRACT

In order to meet and maintain ambient air quality standards called for in the Clean Air Act of 1970, specifically, "nondegradation" of air quality presently better than the national standards, it was felt that a study was needed of alternative means for the control of high emission source-clustering.

Three such policies are considered in this study: air pollution impact statements; zoning control in two forms, permitted-use zoning and emission-density-limited zoning; and the prediction of air pollution impacts of comprehensive regional land use plans. This report also considers the source-clustering problem in the Chicago area, specifically in relation to the effectiveness of the three investigated control strategies.

1.0 INTRODUCTION

For the past two years, Argonne National Laboratory's Center for Environmental Studies, under the sponsorship of the Land Use Planning Branch of the Office of Air Quality Planning and Standards, has carried out studies to investigate the relationship of air quality to land use guidance and control practices. These studies have used the Chicago metropolitan region as a demonstration area to test the effectiveness of alternative land-use environmental controls. The need for such research stems from the requirement that the federal Environmental Protection Agency ensure the attainment and maintenance of national ambient air quality standards. In addition, the Clean Air Act of 1970 has inspired controversy around questions related to nondegradation of ambient air quality presently better than the national standards.

The exact meaning of "nondegradation" is a question of considerable controversy. In its literal, most narrow interpretation, it could prohibit any increase in emissions (and, therefore, all economic growth) within a region or state. On the other extreme, "nondegradation" could be interpreted as merely indicating that secondary air quality standards must be maintained throughout the state. A specific definition was required in the Argonne National Laboratory study in order to develop the appropriate land use and air quality control strategies to be evaluated and to focus the policy analysis. In this study, significant deterioration of air quality was

defined to have occurred when in any area of an air quality control region, a concentration or cluster of high emission sources had developed. An investigation of a relevant land-use/air-quality control policy would then consist of an evaluation of policies designed to prohibit or discourage the creation of such source clusters.

This interpretation was considered to be a compromise between the extremes of definitions, implying either no economic growth or simply the meeting of air quality standards. If the present air quality standards have been met and maintained, the next stage of control in ensuring that air quality degradation did not occur in presently clean areas was deemed to be the implementation of policies aimed at discouraging potentially dangerous high emission source clusters from forming. In this program, three such control policies have been investigated. These are:

1) Air quality impact statements for large emitters prone to locate in source clusters.

   This strategy would be directed toward reducing the locational concentrations of large industrial sources. The major questions to be answered in the implementation of such a control strategy are: What criteria are appropriate for describing the conditions under which an impact statement should be required? Who should be required to make such impact statements? How can emitters be classified to make such a system of controls administratively feasible?

2) Zoning regulations designed to prohibit the creation of source clusters.

Two forms of zoning were investigated: Permitted-use zoning, which excludes activities from specified areas; and emission-density-limited zoning, which prohibits sources from emitting over a certain level of emissions per acre. Because permitted-use zoning is already wide-spread in the United States, the major question in evaluating its effectiveness as an anti-source-clustering policy is whether the air quality effects of alternative zoning policies can be accurately projected. The very basis of emission-density-limited zoning is aimed at the prohibition of source clusters; in this case, the significant questions are: Can emission-density limits be established to ensure that the imposition of such a regulation will guarantee that air quality standards will be met? Secondly, how does emission-density-limited zoning compare with the more orthodox source control regulations now in effect?

3) The use of comprehensive land-use planning as a long-range method of predicting and avoiding source clusters.

The use of comprehensive land-use planning to guide the developmental practices in a region along environmentally acceptable lines has generated considerable interest in the past few years. A critical question to be examined is whether the air quality impacts of land-use plans can be accurately predicted using information commonly generated in the planning process.

The remainder of this summary report will discuss the source-clustering problem in the Chicago area, and summarize briefly the findings of our investigations with respect to the relative effectiveness of these three

policy options. Volume II of this report discusses in detail the development of land-use-based emission factors and their use in estimating air quality from land-use plans. Volume III evaluates the effectiveness of alternative land-use control policies available to planners and compares this approach with the traditional technology-oriented, point-source controls currently used in air quality enforcement programs.

2.0 SIGNIFICANCE OF SOURCE CLUSTERING IN THE CHICAGO AREA

The first step in the investigation of anti-clustering policies was to describe the type of source clusters occurring in the Chicago area and to evaluate the extent of such clustering phenomena. In evaluating control policies designed to discourage source clusters, three characteristics are of major importance: their present size and extent, the probability of the economic growth of such clusters, and the air quality effects.

In the Chicago area, a number of high concentrations of emitters were identified. On the near south side of Chicago, a concentration of coal-fired, space-heating apartments created a severe problem particularly during the colder part of the heating season. Figure 2.1 shows the air quality concentrations of sulfur dioxide (as represented by "isopleths" or lines of constant concentrations) due to these sources. The severe effects of this residential clustering of coal-fired space heating has led the State of Illinois to propose a ban on the use of coal for space heating within the Chicago Metropolitan Air Quality Control Region cannot meet the air quality standards for particulates by 1975. The long-run significance of such residential space-heating source clusters is somewhat diminished due to the fact that from the mid-1960s to the present time, there has been a significant shift in the use of fuels for residential space heating from coal to gas and oil in the Chicago area. It has been hypothesized that

Figure 2.1. Isopleths of sulfur dioxide* due to heavy residential/commercial emissions.
*($\mu g/m^3$ - arithmetic mean)

this market trend will alleviate the requirement for specific legislation to control this form of source clustering. An investigation is now underway as part of a joint research project of The University of Chicago and Argonne National Laboratory to determine if the present trends in residential fuel markets will indeed be sufficient to discourage the development of this form of source clustering in the future.

Significant industrial concentrations of polluters were also found within the Chicago region. The economic factors that cause such industrial agglomeration are still far from well understood, but the air quality effects of such concentrations are evident. In Figures 2.2 and 2.3, the respective pollution concentration caused by the refining and steel industries in the Chicago area are shown. In the case of the steel complex, the air quality effects of this concentration are superimposed upon the effects of the residential space heating concentration mentioned previously. Due to the high level of development of land in the areas adjacent to the steel complex, it is quite unlikely that the source cluster will continue to grow. This is not the case, however, with respect to the refining industry. It is projected that refining and chemical products will enjoy a 50% growth rate over the next 7-10 years and that a majority of this growth will occur primarily in one of the seven counties comprising the Chicago Air Quality Control Region.

The significance of the third type of source cluster—the concentration of commercial activities within the central business district of Chicago—lies more in its induced effects of concentrating an enormous amount of vehicular traffic in a small area. As yet, no air quality estimates have been made using calibrated air quality models within the region. However, the emission density map for carbon monoxide in

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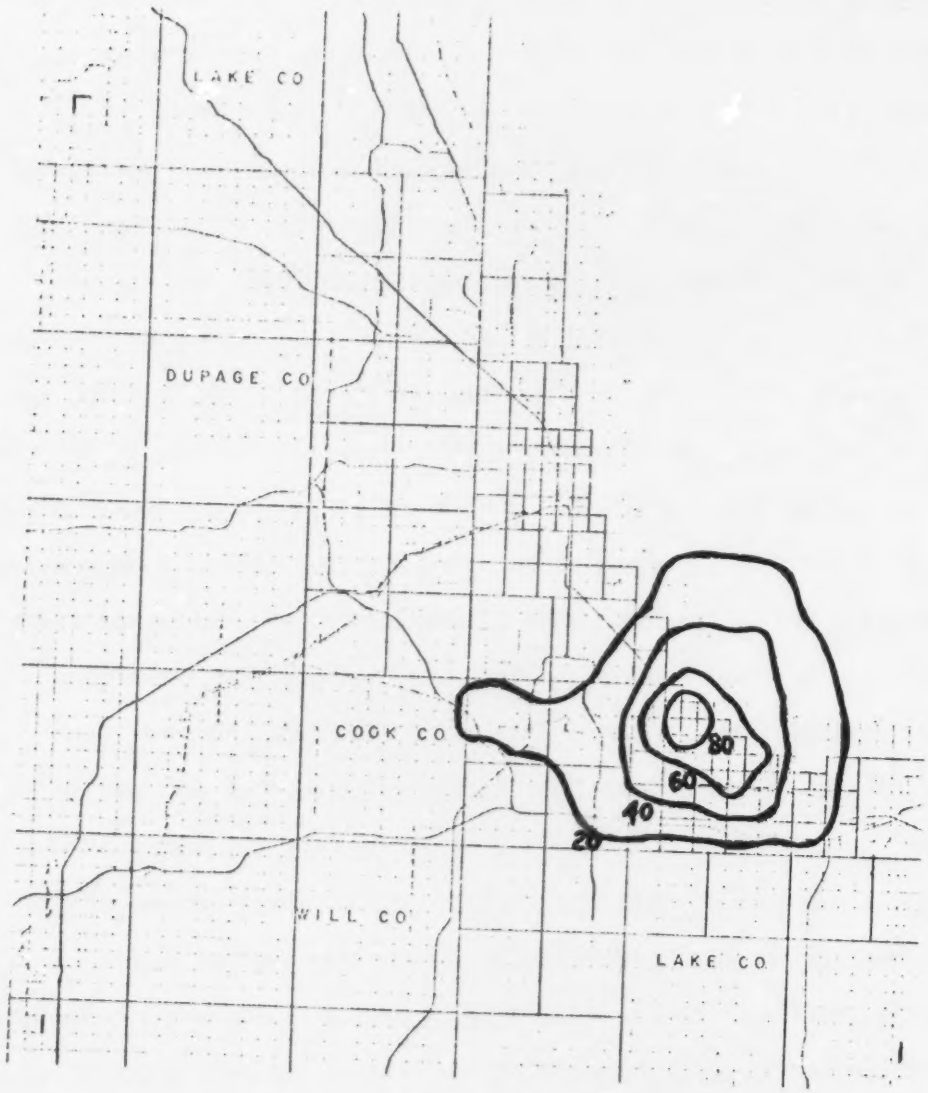

Figure 2.2. Isopleths of sulfur dioxide* due to steel mill emissions.
*($\mu g/m^3$ - arithmetic mean)

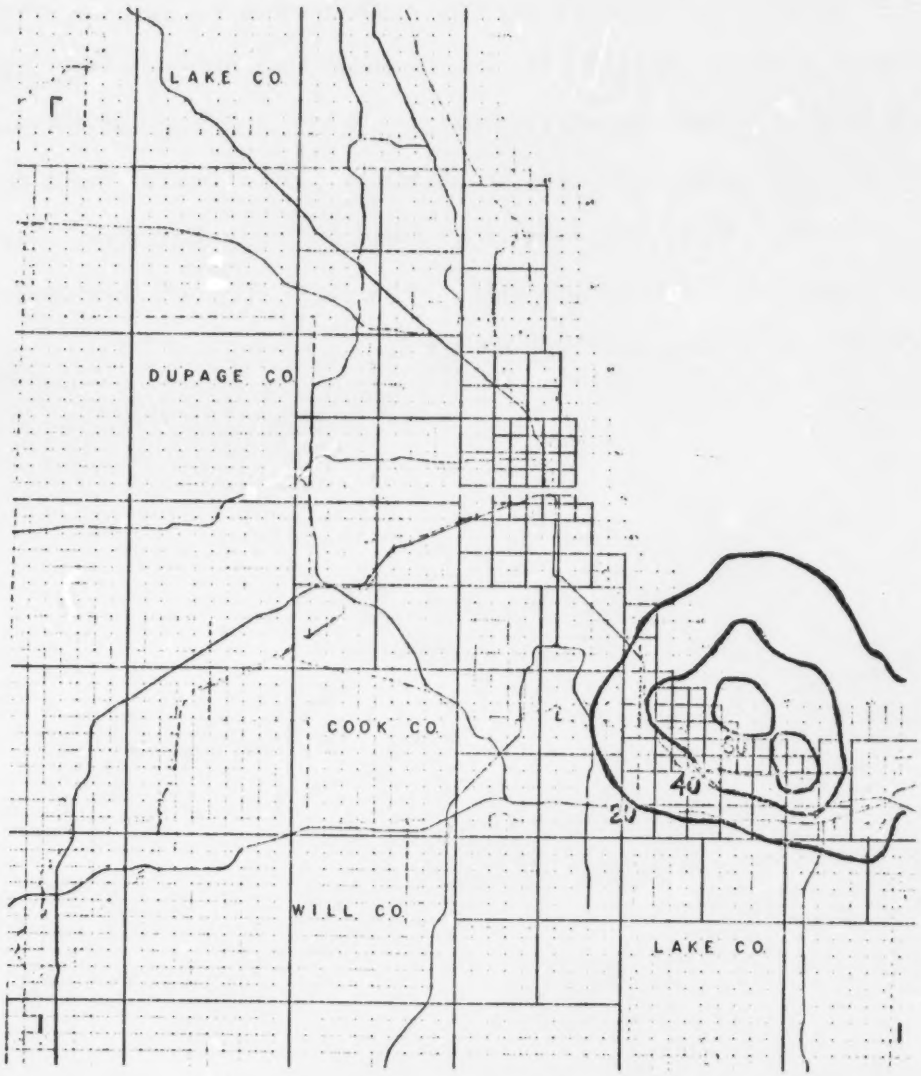

Figure 2.3. Isopleths of sulfur dioxide* due to petroleum plant emissions.
*($\mu g/m^3$ - arithmetic mean)

Figure 2.4 indicates in a general way the severity of the induced air quality effects of this intense concentration of commercial and recreational activities. Based upon Chicago Area Transportation Study estimates of the distribution of growth of vehicular miles in the Chicago area, the central business district has already reached a near-saturation level of peak-hour traffic. Thus, it may be concluded that although this situation constitutes a serious source-clustering problem in Chicago at the present time, the problem is not likely to be aggravated in already large and well-developed urban areas with centralized business districts. For cities whose commercial districts are still in an early stage of development, this assumption, of course, will not be valid.

Figure 2.4. Isopleths of carbon monoxide emission density. (tons/day/square mile)

3.0 PERMIT SYSTEMS AS A MECHANISM TO MONITOR SOURCE CLUSTERING

Present permit practices are directed toward one of two objectives: the evaluation of the application of control technology to the operation of pollution-producing equipment in the case of most state permit systems; or the evaluation of the total environmental impact of a single, highly significant source such as a power plant. Neither of these objectives encompasses a mechanism to assess or discourage the creation of a source cluster. Each is essentially directed toward the evaluation of the control and emissions of a single source. It was the objective of this phase of our investigation to assess the practicability of extending the concepts of permits or environmental impact statements so as to define a permit mechanism directed at the phenomenon of source clustering and its air quality consequences.

Figures 2.2 and 2.3 of the previous section indicate graphically that, although such sources as petroleum plants or steel mills do not singly have the impact that fossil fuel power plants have in terms of emissions, they have a tendency to cluster in geographically dense concentrations. Thus, it may be desirable to monitor a wider range of the environmental impact of locational decisions in such industries than is envisioned in present state or federal permit systems. In effect, this type of environmental land use control policy creates a "permit to locate" in addition to the present "permit to operate" and "permit to construct" that are the

normal components of state and federal permit systems. Under such a monitoring system, the states would have power to prohibit firms from locating in certain areas. Permits-to-locate could be withheld not only because of the projected effects of emissions from the sources applying for such permits, but also because of present and projected ambient concentrations of pollutants within the immediate area.

The major administrative difficulty in implementing such a monitoring and controlling mechanism over the growth of stationary source emission clusters is to define the conditions under which such a permit-to-locate should be required. Obviously, many sources of air pollution will not be significant enough to materially affect air quality concentrations. More importantly, requiring a review of each industry with a pollution-producing source in order to evaluate the areawide air quality effects of its decision to locate would put a large administrative burden on the state. Two mechanisms by which certain industries could be selectively required to prepare and to submit such a permit-to-locate may be hypothesized:

(a) The state could be divided into air quality districts much smaller than the present air quality control regions and permit requirements could be defined such that, if any given district has a total emission level exceeding some standard, all new firms having pollution-producing equipment and wishing to locate there be required to obtain a permit-to-locate. Alternatively, the air quality in each such sector could be measured and projected using the dispersion models, and a set of air pollution concentration standards somewhat below the present secondary standards could be defined. When projections indicate such air pollution levels will be reached within five or so years, any new polluters wishing to locate in the region would have to obtain a

permit-to-locate. In all probability, such permits would require information regarding area source emissions and air quality that only the state or local environmental protection agencies would have available. Therefore, it would be anticipated that the development of such a permit-to-locate would be a joint effort of the local air quality control agency and the industry in question. Under such a system, any industry desiring to locate in the area of the petroleum and steel industrial complexes shown in Figures 2.2 and 2.3 would be required, in conjunction with the local air pollution officials, to assess the total areawide effects of its location.

(b) A ranking of pollution sources according to some standard industrial classification scheme could be made and those industries in the highest ranking classifications could be required to obtain a permit-to-locate. This technique would reduce the required number of permits-to-locate on the basis of the average emission levels of polluters in that industrial category. The major problem with this approach is in estimating the average emissions based upon any of the presently defined industrial classifications. Attempts were made in the Argonne study to classify average particulate and sulfur dioxide emissions according to 2-digit standard industrial classification categories. The difficulty in using this classification scheme in identifying requirements for a permit-to-locate is the large variance of emissions for polluters within a given industrial classification sector. For example, even though the average emissions from the primary metal industries—SIC 33—are about equal to the average emissions of the chemical and allied industrial

sector—SIC 28—(based on analysis of the Chicago emission inventory), the variation in emissions in the chemical sector is 25-30% higher than the variation in the primary metals industry. Although their average emissions are approximately equal, the environmental risk of allowing a petroleum plant to locate within a region is greater than of allowing a primary metal plant to locate there; there is a greater possibility that the given petroleum plant will have much higher emissions than the industrial average.

Because of this variance problem in employing standard industrial classifications to rank emissions, a further investigation was carried out to rank industries both by their average emissions and by the standard deviation associated with these average estimates as illustrated in Figure 3.1. It has been assumed that the Illinois source regulations are in effect. Figure 3.1 also indicates that, in terms of pollution potential as measured by the mean and standard deviation of particulate emissions, six industries could be singled out as having emissions large enough to warrant a more extensive evaluation of the air quality effects of their locational decisions. These are the following:

1. food and kindred products (SIC 20)
2. paper and allied industries (SIC 26)
3. chemical and allied industries (SIC 28)
4. petroleum and coal industries (SIC 29)
5. the stone, clay, and glass industry (SIC 32)
6. the primary metals industry (SIC 33)

In the Chicago area, it has already been demonstrated that the primary metals and chemical and allied industrial complexes in the southern part of the Chicago Air Quality Control Region do represent significant dangers by reason of their source clustering characteristics.

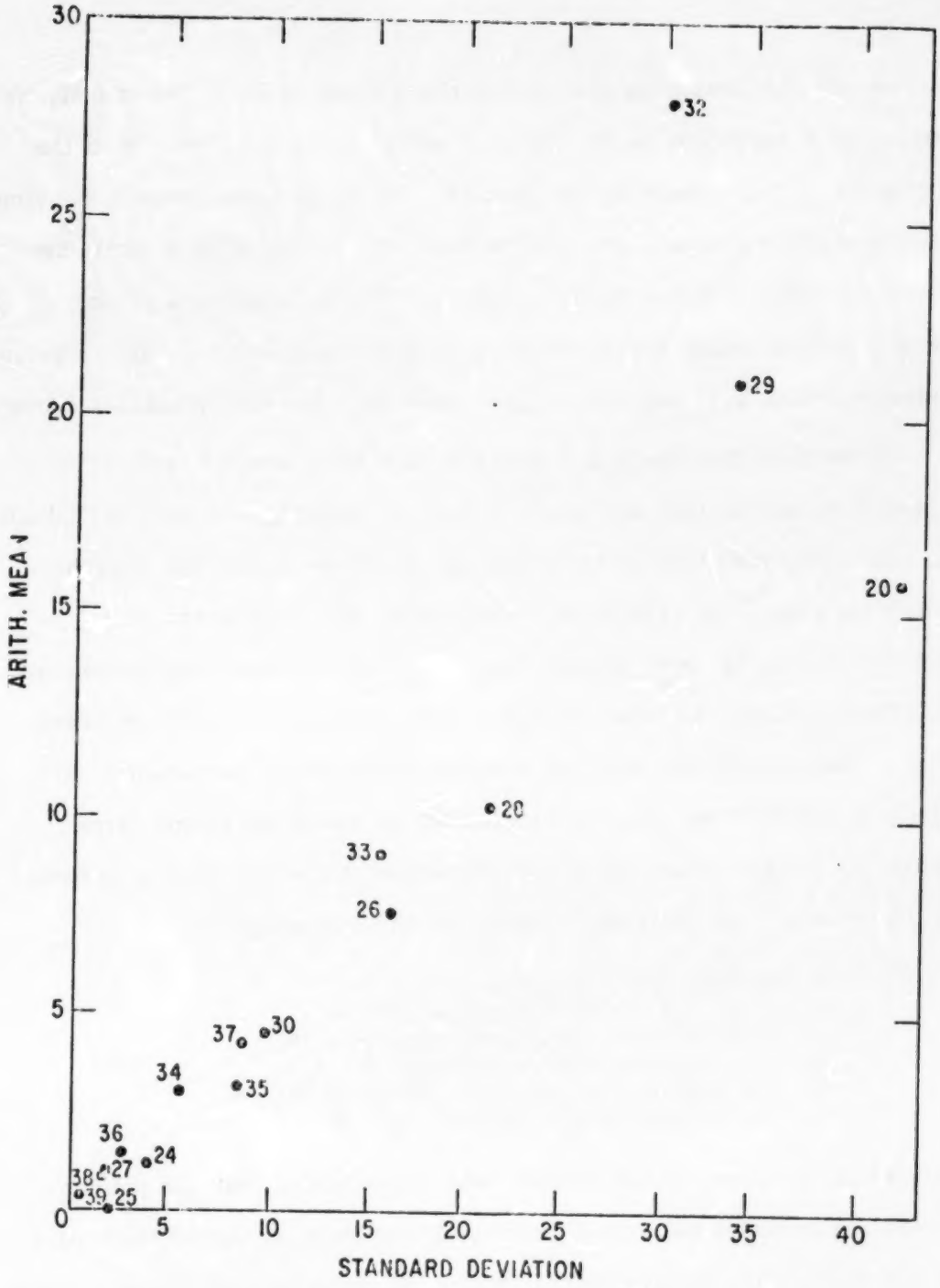

Figure 3.1. Mean suspended particulate emissions (lbs/hr) vs. standard deviations by two-digit SIC classification with Illinois source control regulations applied.

Naturally, the industrial mix and location of industries within the Chicago area will be different from those found in other areas of the country. To draw more valid conclusions as to the practicability and desirability of encouraging states to broaden the concepts of permits in monitoring the growth of source clusters, it would be desirable to assess the existence of such high emission source clusters in other regions of the country, using the national emission data file developed by the Environmental Protection Agency.

4.0 ZONING AS A MECHANISM FOR CONTROLLING THE DEVELOPMENT OF SOURCE CLUSTERS

One of the objectives of the Argonne National Laboratory study was to make an investigation of both permitted-use zoning and emission-density-limited zoning as alternative mechanisms for environmental land use control. It was found that the classification scheme used in most of the normal permitted-use zoning regulations was too coarse in structure, particularly in the areas of heavy and light industrial zoning classes, to provide an effective means of measuring change in air quality due to changes in standard zoning regulations. Subsequent investigations concentrated, therefore, on the emission-density-limited zoning.

The central concept behind emission-density-limited zoning is that the density of emissions (i.e., the pounds of emissions per square mile or acre per unit time) should be the basis for regulation rather than just the level of emissions of given sources. Emission-density regulation, by definition, would restrict the growth of source clusters, because it explicitly takes into account the density of emission sources. Emission-density limits preclude large emitters from purchasing relatively small amounts of land and locating in areas of high emission density.

Two major questions to be asked with regard to emission-density-limited zoning are: Can emission-density limits be established to ensure that the imposition of such a regulation will guarantee that air quality standards will be met? Secondly, how does emission-density-limited zoning compare with the more orthodox source control regulations now in effect. Using the Chicago emission inventory, several alternative forms of an emission-density-limited zoning regulation were simulated in order to shed light on these questions. Figure 4.1 shows one such simulation; in it emission-density-limited zoning was defined for three categories of polluters. Heavy industrial polluters were prohibited from emitting more than 3.0 tons of particulates per day per square mile; light industrial polluters were prohibited from emitting more than 1.4 tons of particulates per day per square mile; and heavy residential/commercial sources of pollution were prohibited from emitting more than .5 tons per day per square mile. (In these simulations, light industry was defined to be any industry in the Standard Industrial Classifications 20-25 and 34-39. Heavy industrial classifications were those SIC 26-33.) The air quality effects of this regulation are shown in the isopleth map. It should be noted that applying this regulation to uncontrolled emissions in the Chicago area resulted in an estimation of air quality that meets the national ambient air quality standards. Suggested methods and criteria for selecting the emission-density limits are described in Volume III of this report.

In order to evaluate the distribution of the emission reductions required by this regulation, a frequency diagram was generated; it indicates the distribution of sources categorized according to their emission densities. Figures 4.2 and 4.3 show these frequency plots for both heavy and light

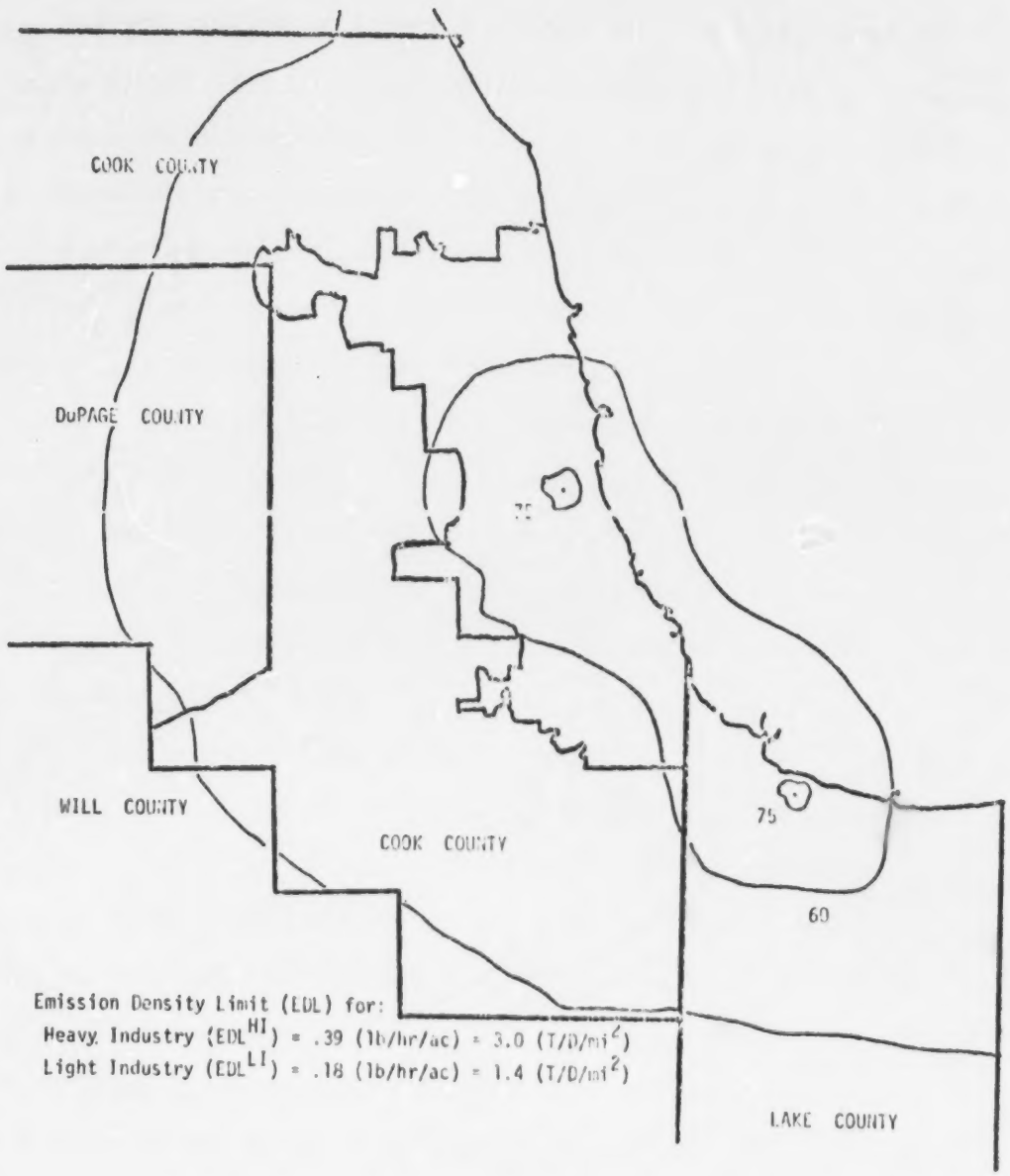

Figure 4.1. Isopleths of suspended particulates* using emission-density limits (EDL) for heavy industry.

*($\mu gm/m^3$ - annual arithmetic mean - uncalibrated model)

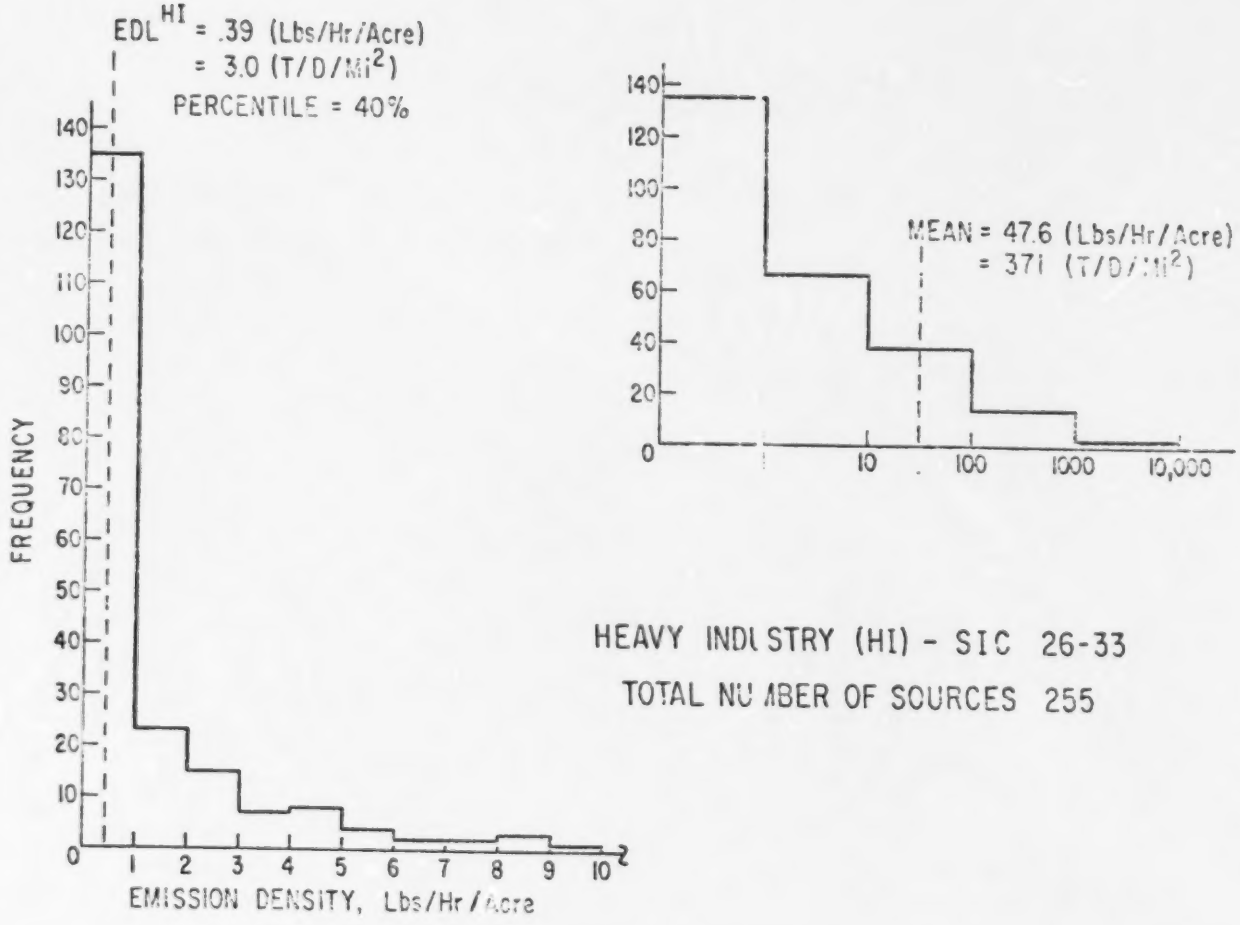

Figure 4.2. Frequency of suspended particulate emission densities for heavy industry.

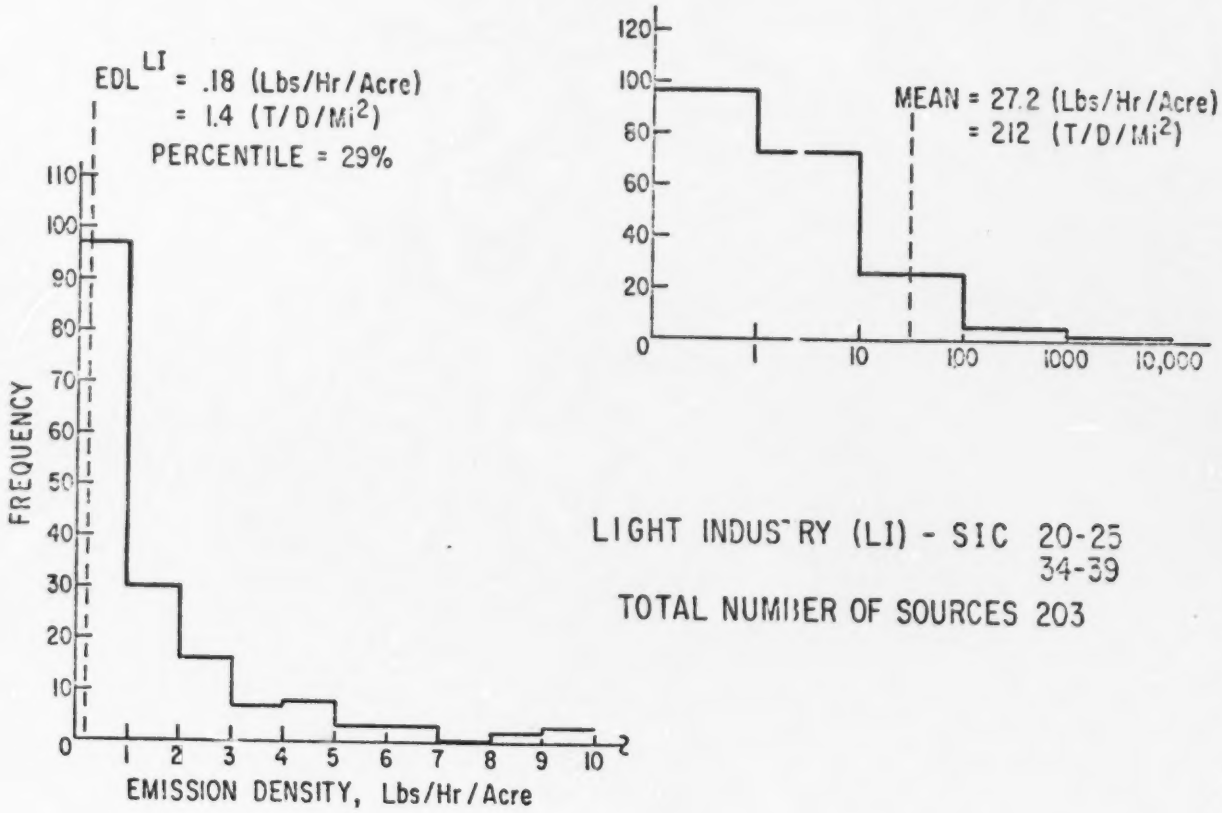

Figure 4.3. Frequency of suspended particulate emission densities for light industry.

industrial source classifications. Due to the significant skewness of these distributions, only about 60% of the heavy industrial emitters were required to reduce their emissions (based upon the three tons per day per square mile emissions-density regulation). In the case of light industrial sources, approximately 70% were affected by the 1.4 tons per day per square mile limit for emission density.

Because the emission-density zoning regulations favor those industries that are more land intensive, it is to be expected that the distribution of the required source reductions under the zoning regulation would be significantly altered from the present distribution of emission reduction under the Illinois source control regulations. The required percentage reduction for those industries in each Standard Industrial Classification category were calculated under the conditions of both the emission-density-limited zoning regulation and the present Illinois source control regulations. Figure 4.4 indicates the results of this analysis. It is rather surprising that the percentage reductions required by the present Illinois law should approximate so closely the required reductions under the zoning regulation.

In summarizing the findings of this analysis with respect to the applicability of emission-density-limited zoning, we should make three major points. The first is that (using the Chicago emission inventory and standard dispersion modeling techniques) a zoning regulation or set of regulations can be formulated to meet the national ambient air quality standards for suspended particulate matter. Second, the results presented in Volume III of the application of a cost model to both types of control in the Chicago region indicate that in terms of immediate costs and effectiveness, the emission-density-limited zoning seems to compare favorably with the present structure of emission control regulations. The third point, and

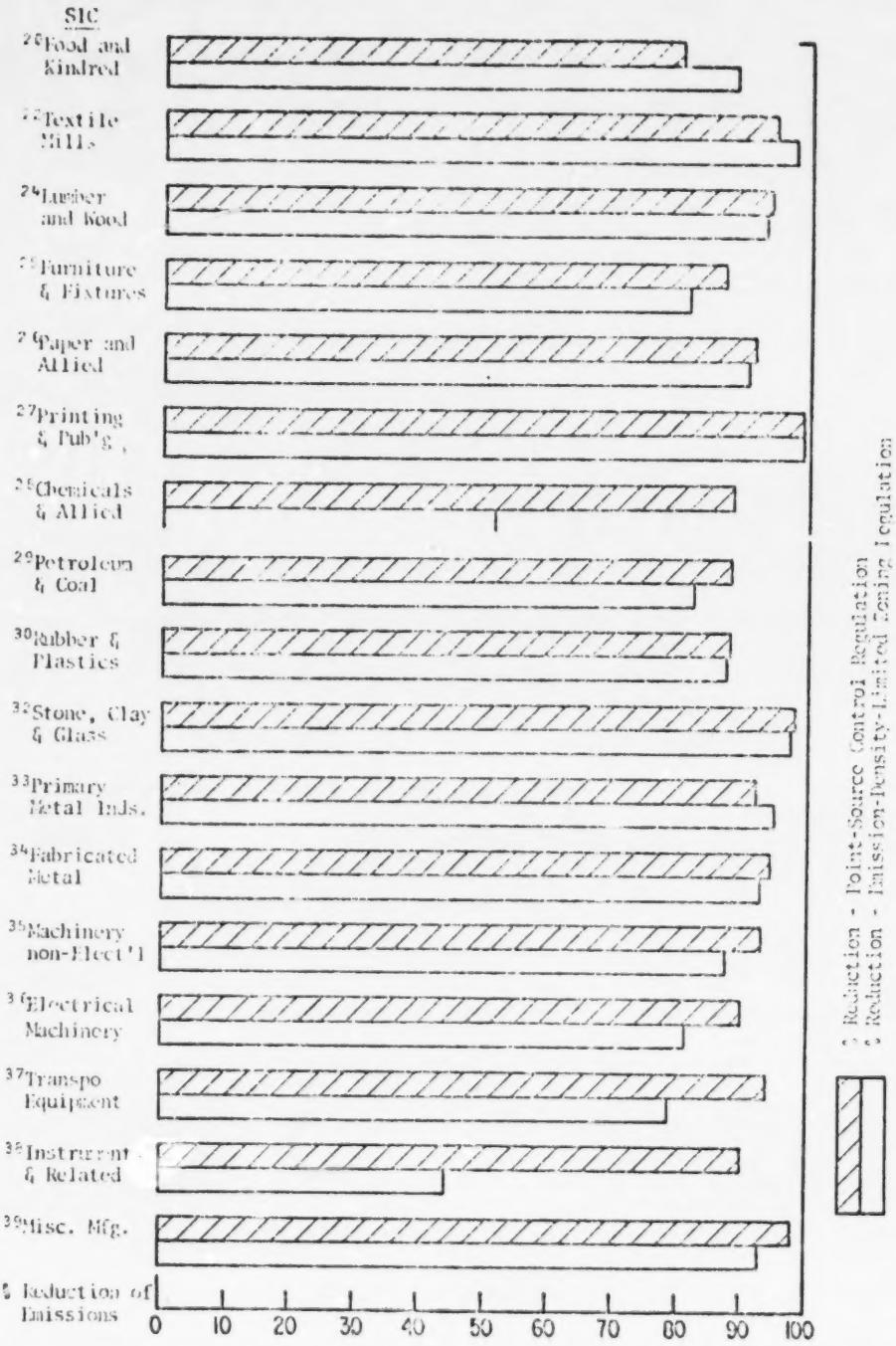
SIC
20 Food and Kindred
22 Textile Mills
24 Lumber and Wood
25 Furniture & Fixtures
26 Paper and Allied
27 Printing & Pub'g.
28 Chemicals & Allied
29 Petroleum & Coal
30 Rubber & Plastics
32 Stone, Clay & Glass
33 Primary Metal Inds.
34 Fabricated Metal
35 Machinery non-Elect'l
36 Electrical Machinery
37 Transpo Equipment
38 Instrument & Related
39 Misc. Mfg.
% Reduction of Emissions
0 10 20 30 40 50 60 70 80 90 100
% Reduction - Point-Source Control Regulation
% Reduction - Emission-Density-Limited Zoning Regulation

Figure 4.4. Comparison of emission reductions for zoning regulations with present Illinois emission controls.

perhaps the most significant in terms of the control of the development of emission source clusters, is that emission-density zoning provides not only a mechanism for attaining air quality standards at the present time, but also ensures that source clusters will not develop in the future.

5.0 PROJECTIONS OF AIR QUALITY VIA COMPREHENSIVE PLANNING

The use of comprehensive land use planning as a mechanism to avoid some of the deleterious environmental consequences of economic development has come under a great deal of discussion in the past few years. The attractiveness of comprehensive land use planning in controlling the long-range environmental quality of a region stems from the fact that entering environmental considerations into the planning process itself, represents the least disruptive method of maintaining environmental quality, while still allowing for sufficient economic growth to ensure the overall viability of the region.

The central question with regard to the use of this method as a mechanism to ensure that dangerously high emission source clustering does not occur in the region is whether the air quality effect of future source clustering phenomena could be accurately represented using projections that are likely to be available in comprehensive land use plans. The projection of ambient air quality depends upon the ability to project the future locations and levels of activity of economic sectors and, using these land use projections, to estimate future emission-density patterns. The ability to make such estimates ultimately resolves itself into a problem of developing and projecting land-use-based emission factors. Using the Chicago Emission Inventory, a number of alternative strategies were employed to generate such factors. Subsequently, these factors were applied to presently available Chicago land use data to evaluate whether the use of these factors

could accurately reproduce estimates of air quality conditions in the Chicago area. Once such factors have been catalogued as a function of planning parameters and their utility tested, they can be applied to proposed land use plans for purposes of evaluating their air quality impacts.

To generate land-use-based emission factors that are compatible with information presently available in comprehensive land use plans, the most direct procedure consists in estimating the present average emission density for each of the major economic sectors represented in the present Chicago Emission Inventory. These sectors can be classified into either zoning or standard industrial classifications. Figure 5.1 shows the emission density distribution of industrial class sources within the Chicago area. Not only is the standard deviation of this distribution quite high in relation to its average, but the skewness of the distribution causes significant estimation problems if the mean of 9.0 $T/D/mi^2$ is used as an emission density factor in projecting future air quality. Figure 5.2 shows the calculated air quality for suspended particulates as derived by applying a 9.0 $T/D/mi^2$ emission-density factor to the present industrial land use pattern in the City of Chicago. Figure 5.3 shows the suspended particulate air quality estimates based directly upon the application of standard emission factors to the Chicago Emission Inventory. The use of the average emission-density factor for industrial lands did produce average air quality estimates that approximated the average air quality over the entire region. However, due to a bias in estimating this factor, pockets of very high concentrations seem to appear. Thus, air quality estimates based on average emission-density factors, as opposed to estimates based on actual point-source emissions, would be unrepresentative. If these air

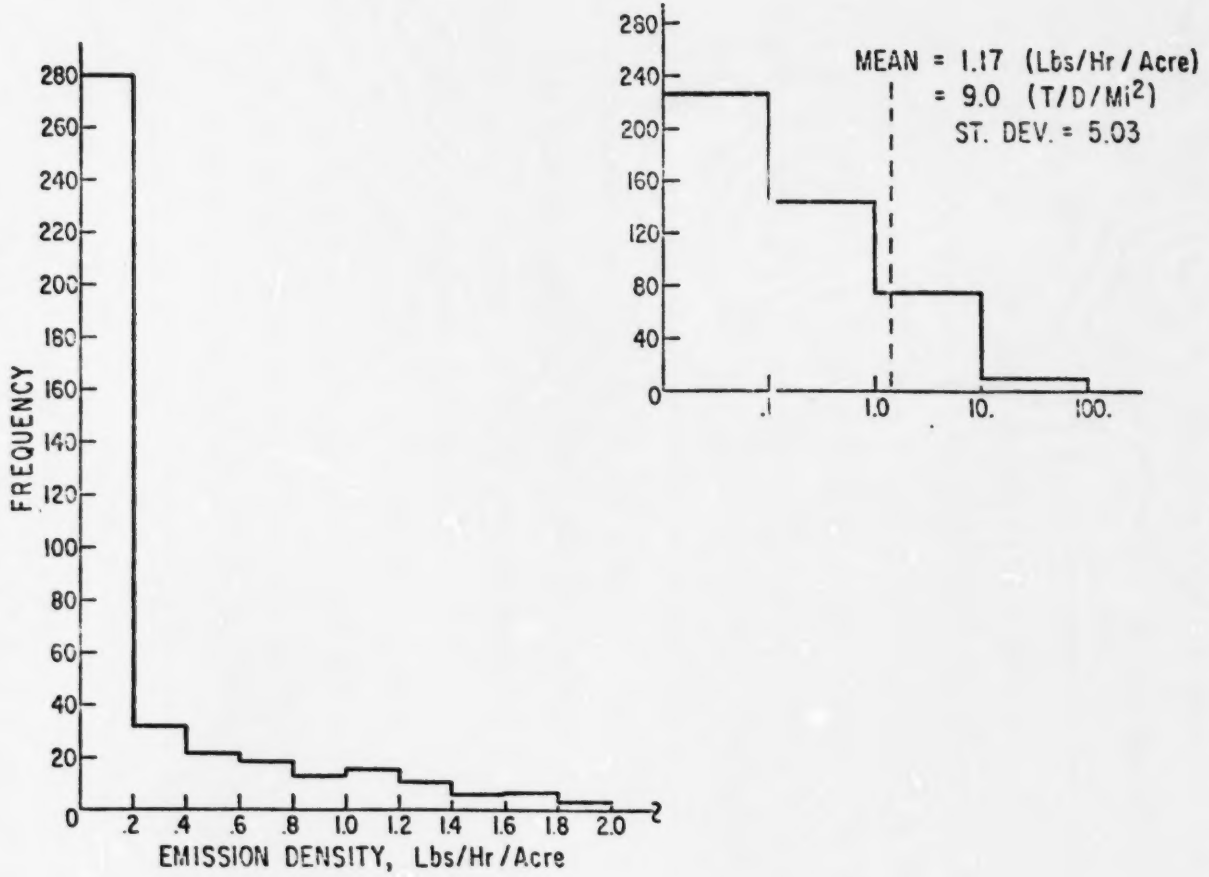

Figure 5.1. Frequency of suspended particulate emission densities for total manufacturing with Illinois source control regulations applied.

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Figure 5.2 Isopleths of suspended particulates* using mean emission-density estimates for manufacturing land.
(mean $\equiv$ 9.0 T/D/Mi^2 = 1.17 lb/hr/acre)
(*$\mu g/m^3$ - annual geometric mean)

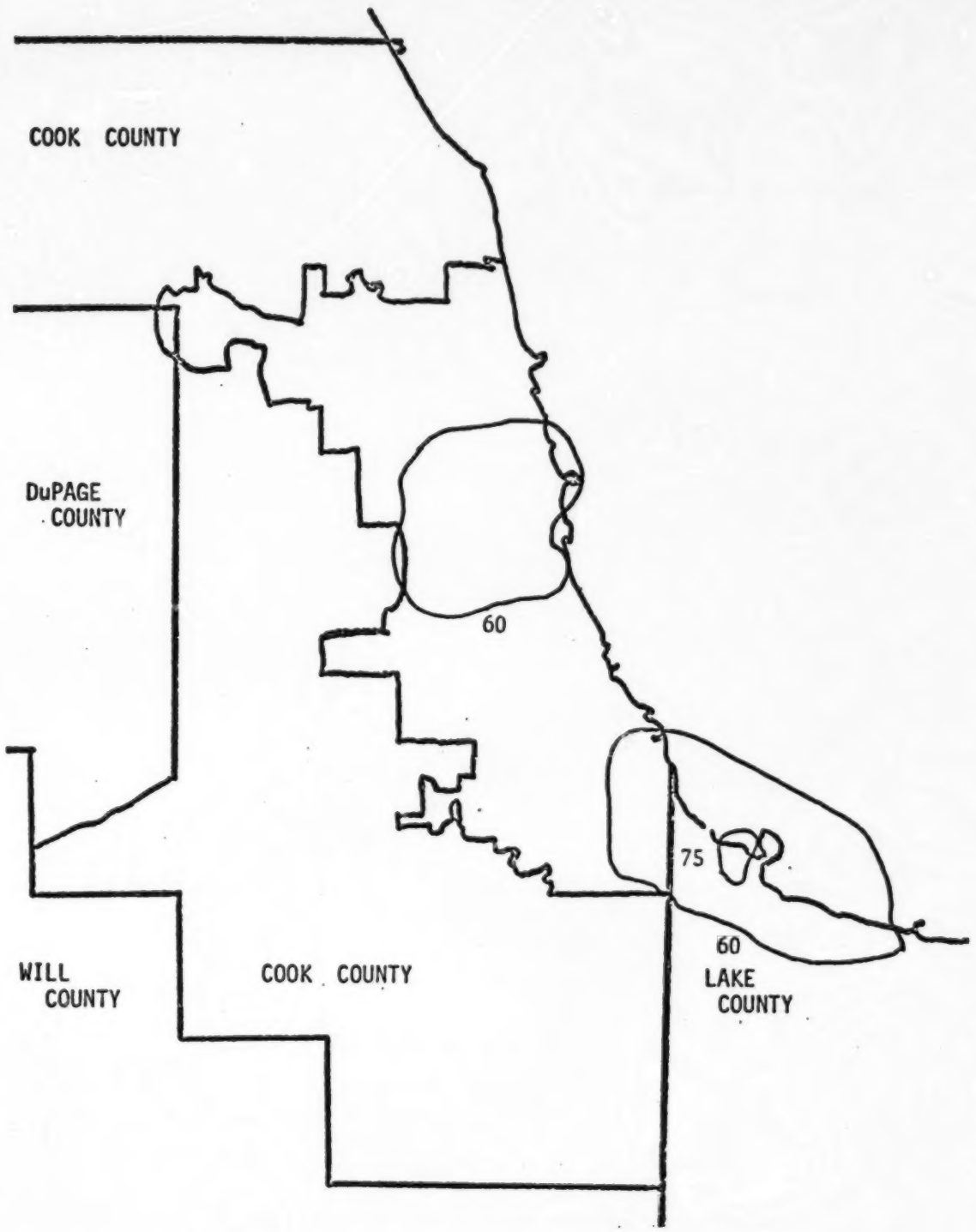

Figure 5.3. Isopleths of suspended particulates* with Illinois source control regulations applied.

*($\mu g/m^3$ annual geometric mean)

quality estimates were used in ranking alternative land use plans or in trying to identify future potential source clusters in the Chicago area, one might conclude that air quality standards will not be met under the present conditions of Chicago land use patterns and air quality regulations.

This does not mean that the projections of air quality using these estimators are not a useful tool in ranking the air quality effects of alternative land use plans. Due to the bias of the land use emission-density factor estimates, those plans containing a larger percentage of industrial zoned land will, in all probability, be ranked as being likely to produce more significant degradation of air quality than might otherwise be. It is therefore our recommendation that, in using the mean estimators for land-use-based emission densities, some method be developed to specifically take into account the skewness and variance of these distributions in projecting future air quality.

A major source of the variance in the emission factor estimates is caused by the industrial process sources. In Figures 5.4 and 5.5, respectively, the present distribution of emission densities for fuel combustion and process sources are shown. An examination of the standard deviation of these distributions compared with the standard deviation of the frequency distribution of the emission densities for the industrial sector as a whole indicates that almost the entire variance in the emission-density estimate is due to the variance of emissions in process sources. Thus, it can be anticipated that, if present land use industrial projections could be disaggregated into process and fuel combustion sources, the projected air quality estimates would be somewhat improved. This does not alleviate the need, however, to specifically account for the wide variation in emission densities

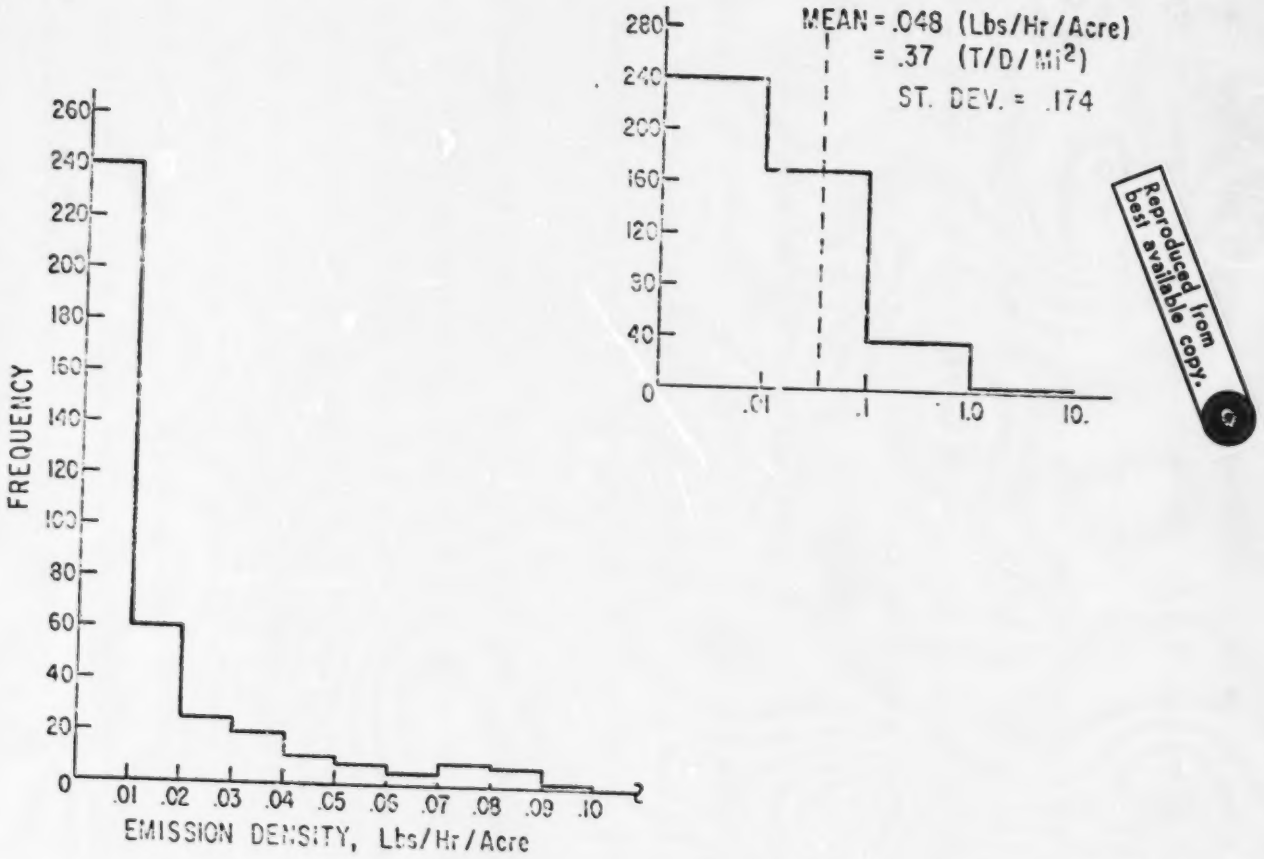

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Figure 5.4. Frequency of suspended particulate fuel combustion emission density with Illinois source control regulations applied.

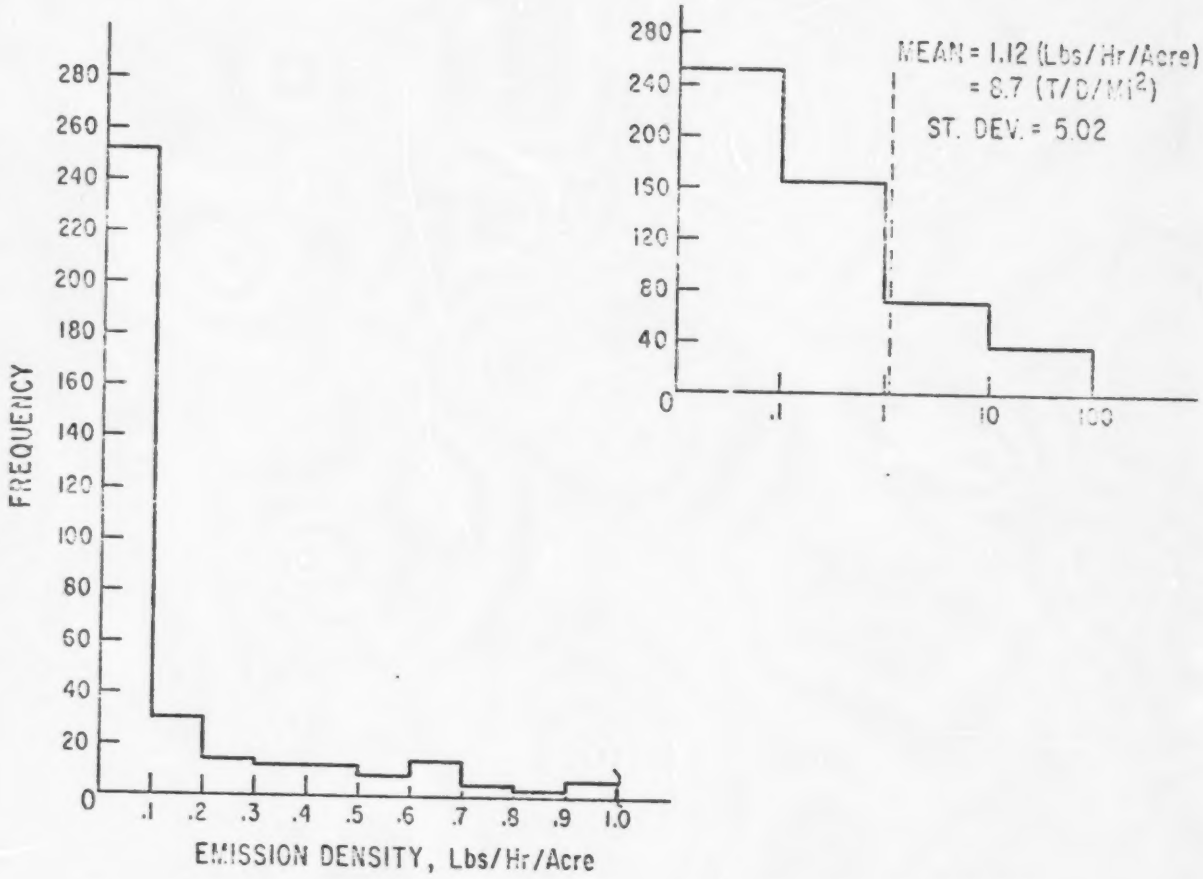

Figure 5.5. Frequency of suspended particulate process emission density with Illinois source control regulations applied.

for industrial process sources. Volume II of this report details some of the methods used to explain this variance, using planning parameters such as standard zoning and industrial classification systems, employment, and land use.

6.0 CONCLUSIONS AND RECOMMENDATIONS

In reviewing the applicability of the alternative methods of ensuring that source clusterings do not develop as a serious threat to air quality, it must be recognized that the evaluation made thus far has been carried out independently of any considerations of the administrative difficulty in implementing the proposed strategies. The results of this investigation have indicated, however, that these strategies do represent in some cases viable alternatives or adjuncts to the present structure of air quality control regulations.

It should also be recognized that the applicability and significance of these strategies depends upon the present priority of land use and environmental control programs. If the future clustering of large industrial emission sources presents the only significant air quality degradation problem, the use of permit systems to reduce source clustering would seem to be the most easily implemented strategy. On the other hand, if a broad range of land use developmental practices constitutes the cause of emission source clustering in large metropolitan areas, more comprehensive approaches such as emission-density-limited zoning or the use of comprehensive planning in avoiding such practices will be necessary.

The following specific conclusions, substantiated in Volumes II and III of this report, have been drawn from this study.

SUMMARY OF CONCLUSIONS

1. Source clustering in the Chicago region is a major problem, even with control technology applied, and will pose the major threat to air quality maintenance in the long run.
2. The major significant source clusters will be industrial process or induced traffic due to concentrations of intense residential/commercial land use. Residential/commercial fuel combustion will not be a problem, assuming the availability of clean fuels.
3. Anti-source clustering policies and the long-run deterioration of currently clean air zones have not been adequately addressed on local, state, or federal levels. Options for anti-clustering control include:
   a. An impact statement or permit-to-locate system;
   b. A zoning control system;
   c. A comprehensive planning process that includes air quality impact analysis.
4. An impact statement policy can be based on the two-digit SIC classification.
5. Emission-density zoning is an effective long-range control and is no more costly than point-source control, assuming a stable zoning process. In addition, deterioration in air quality is predictable and controlled virtually by the definition of the density limitation.
6. Comprehensive planning as a control mechanism depends on: (1) the stability of the plan over time; (2) the ability of public administrators to implement the plan; and (3) the ability of planners to forecast the air quality effects of land use

decisions and policies and to rank land use plans. The latter element of the process has been tested extensively in this study with only sporadically successful results to date. The major problem concerns the wide variance and skewness in emission-density distribution for manufacturing land use. Because of the nature of these distributions, severe distortions in air quality representations occur when mean estimates are employed.

The following recommendations with regard to long-run maintenance of air quality standards are made as a result of this study.

SUMMARY OF RECOMMENDATIONS

1. The policies for maintaining air quality at standards should be defined in terms of controls aimed at the discouraging high emission-density source clusters. Therefore, the EPA should conduct a national study of significant source clusters in major metropolitan areas.
2. It is recommended that one or more of the following policies be encouraged by the EPA for state implementation as an anti-source clustering strategy:
   a. An impact statement or permit-to-locate system;
   b. A zoning control system;
   c. A comprehensive planning process that includes air quality impact analysis.
3. If this national policy employs impact statements or "permit-to-locate" systems as control mechanisms, a determination of appropriate criteria for the application of these policies and the development of administrative procedures are required.

4. If the national policy employs emission-density-limited zoning, a national study of levels of effective density limits and costs is required, along with the admininstrative methods of implementing such a policy. Model emission-density-limited zoning regulations should be developed as a result of this study.
5. If the national policy employs comprehensive planning, new methods for ranking land use plans that include a realistic appraisal of the risks of air quality deterioration are required. Before a standardized air quality analysis procedure can be adopted by the planning community, methods for explaining the variance in emission densities, or otherwise accounting for this variance by simulation procedures, is required.

The following Table 6.1 summarizes in detail the results of this study, as described in Volumes I, II, and III of this report.

Table 6.1. STUDY SUMMARY

ANTI-SOURCE-CLUSTERING POLICY	ANALYTICAL METHODS	RESULTS AND CONCLUSIONS	REMAINING PROBLEM AREAS	RESULTANT FEDERAL POLICIES	FURTHER STUDIES NEEDED
LOCATIONAL PERMITS AND IMPACT STATEMENTS	• Source-clustering identification using dispersion modeling. • Analysis of variance in industrial emissions by 2-digit SIC code.	• Large variance occurs within 2-digit SIC groups. • Mean and standard deviation of emissions can be used to rank industrial emissions by 2-digit SIC code.	• Criteria must be established for requiring locational permits or impact statements. • Legal activity and administrative procedures are required.	• Define areas of critical concern. • Guidelines for use of locational permits and impact statements. • Create administrative mechanisms for implementing source-clustering control via locational permits or impact statements.	• National assessment of of source-clustering problem. • Evaluation of alternative administrative procedures for implementing locational permits or impact statements as methods of source-clustering control.
ZONING PERMITTED-USE EMISSION-DENSITY LIMITED	• Analysis of variance in emission densities by zoning class. • Use of emission-density estimates in representing air quality. • Cost-effectiveness comparison of point-source control regulations and emission-density-limited zoning as approaches to regional air quality maintenance and control.	• Emission densities by "traditional" permitted-use zoning do vary significantly, but do not provide adequate air quality representation. • Emission-density-limited zoning is effective in controlling and maintaining air quality. Further, the control cost to current sources does not significantly increase over point-source control regulations now in existence.	• Acceptance of emission-density-limited zoning as a viable concept for air pollution control. • Administrative arrangements between air pollution control officials and zoning administrators.	• Model zoning ordinances. • Guidelines for including air quality in the zoning process.	• National study of levels of cost-effective emission-density limits. • Develop and compare model emission-density-limited zoning ordinances for major metropolitan areas.
COMPREHENSIVE PLANNING PROCESS	• Analysis of variance in emission densities by land use class and 2-digit SIC code. • Use of emission-density estimates in representing air quality. • Product-moment correlation, simple and multiple regression.	• Major problems occur with wide variance in emission densities causing distortions when predicting air quality from land use. • Incomplete data available, particularly for predicting industrial process emissions. • Dwelling unit density or floor area ratios proved useful in predicting energy use from residential and commercial land use.	• Interface between planning agencies and air pollution control agencies ill-defined. • Determine variables useful in predicting process emissions. • Test utility of employment and other intensity measures in predicting air quality via dispersion modeling.	• Define procedures for analysis of air quality impacts of land use and urban development. • Specify required data collection, publication, and use procedures. • Specify air pollution planning agency working relationships.	• Further tests of predicting air quality effects of land use, using intensity of land use measures. • Develop reasonable growth projection methods and test their ability to predict air quality deterioration.